living planet symposium
13–17 May 2019 | Milan

SENTINEL-3A/B

LAGEOS 1/2

Determination of global geodetic parameters and station coordinates based on SLR measurements to reduced-dynamic Sentinel-3A/3B orbits

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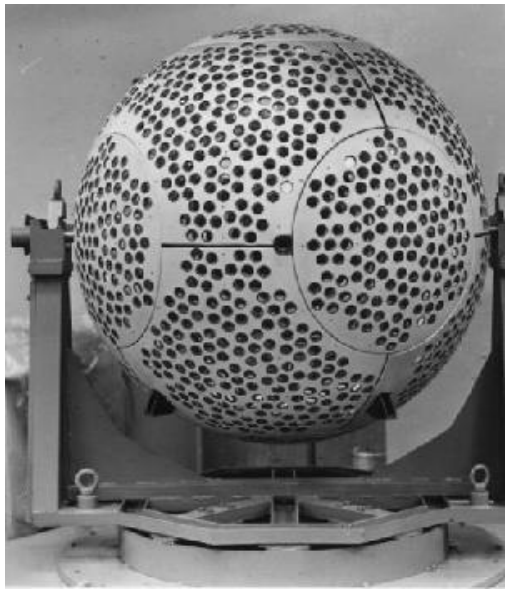
Motivation

LAGEOS1/2

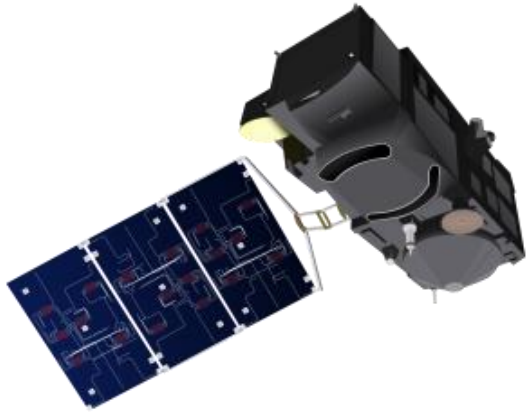


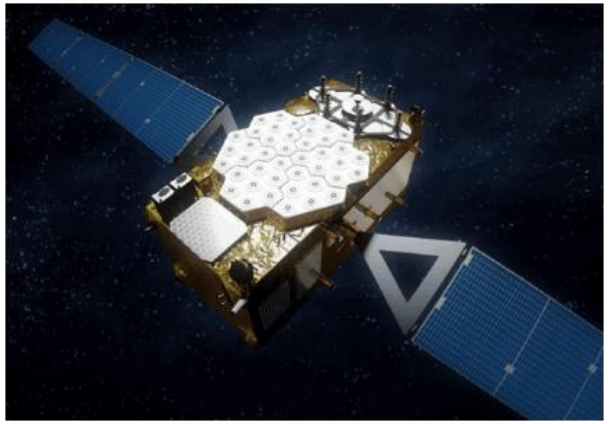
Etalon 1/2

Satellite Laser Ranging (SLR) measurements to passive geodetic satellites (LAGEOS & Etalon) are used for the realization of reference frames (e.g. ITRF2014)

Motivation

retroreflectors



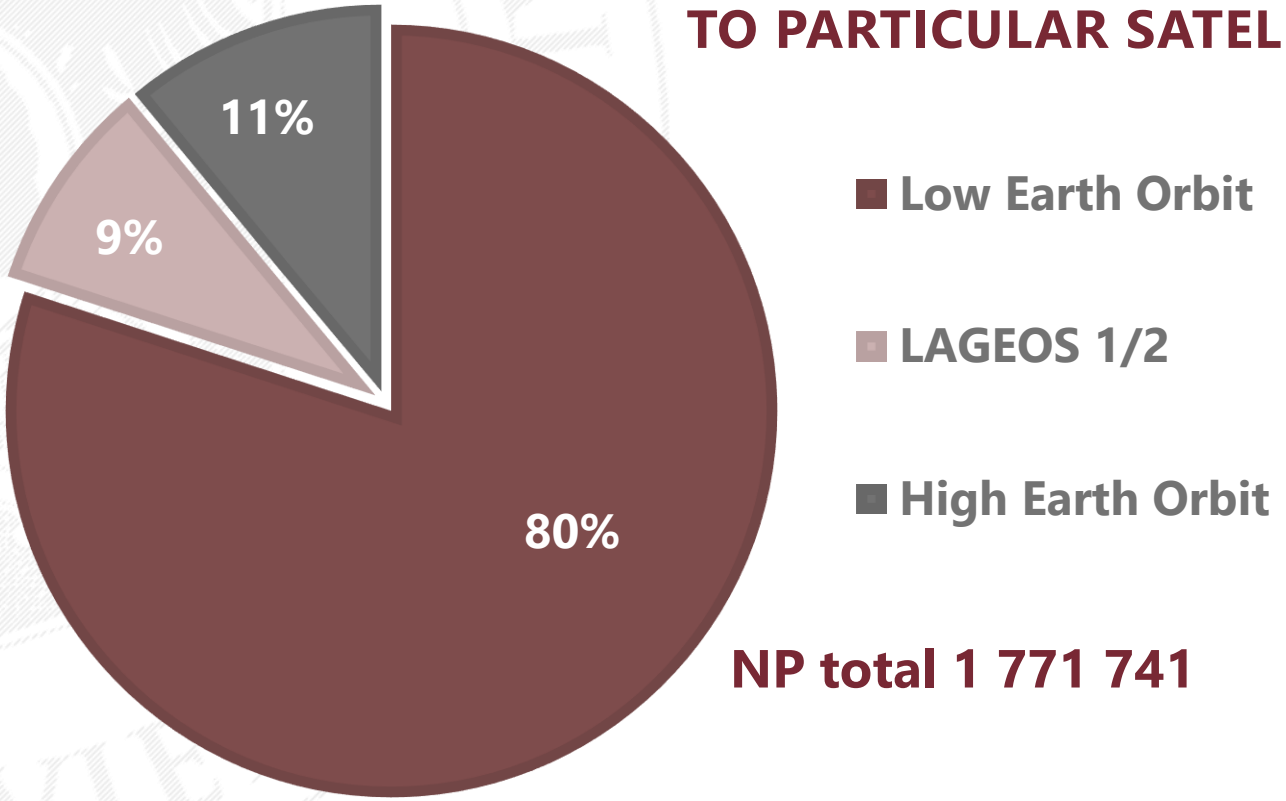


GNSS or active Low Earth orbit (LEO) satellites are equipped with retroreflctors, which allow for SLR measurements

Motivation

International Laser Ranging Service (ILRS) initiates a series of intense tracking campaigns for GNSS and LEO satellites

PERCENTAGE OF SLR OBSERVATIONS (NORMAL POINTS) TO PARTICULAR SATELLITE TYPES IN 2017



NP total 1 771 741

Only 9% of all SLR measurements are used currently for the reference frames realization, determination of Earth rotation parameters (ERP), and geocenter coordinates

SLR measurements

Sentinels-3A/B

- *ESA and EUMETSAT*
- *active LEO satellite*
- *altitude 815 km*

- ***the only satellites in the Sentinel constellation equipped with retroreflectors dedicated for SLR***
- *DORIS and GNSS receivers*
- *Precise GPS-based orbits and attitude data*

Active satellites → SLR → orbit validation

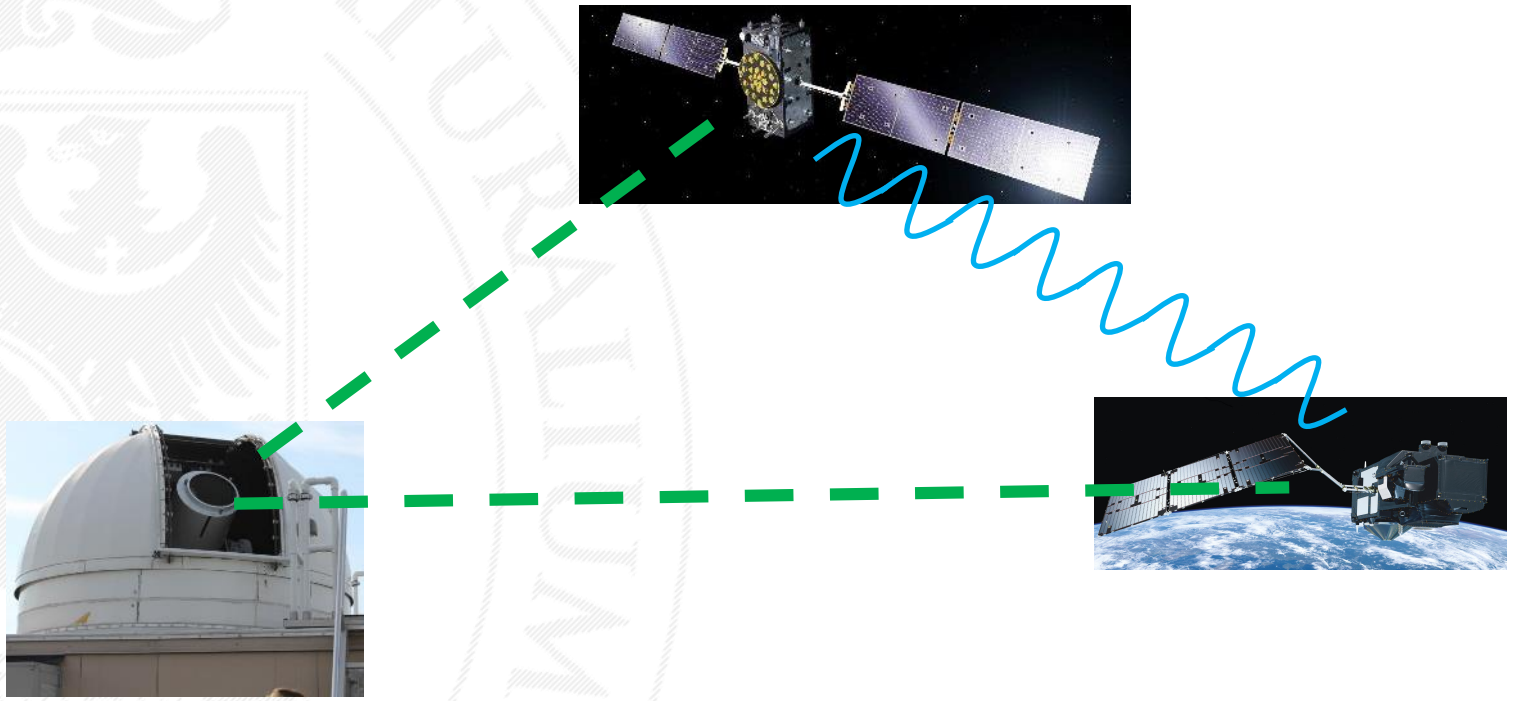
LAGEOS-1, LAGEOS-2

- *NASA and ASI*
- *used for relativistic effects, gravity field, geodynamics, ERP, geocenter coordinates research by SLR measurements*

- *passive, spherical, geodetic satellites, with low area-to-mass ratio*
- *eqiupped with 426 retroreflectors dedicated for SLR technique*

Passive satellites → SLR → station coordinates, geocenter coordinates, ERP, scale, relativistic effects validation

Motivation



ITRF

GEOCENTER ?

ERP

SLR observations to active LEO & GNSS for the realization of ITRF and global geodetic parameters?

laser

microwave

Sentinel 3A/B GNSS- and SLR- based analysis

LAGEOS

GPS

Sentinel-3A/B

SLR site

laser

microwave

SLR normal points + High-quality GPS-based Sentinel-3A/B orbits and orientation data (AIUB)

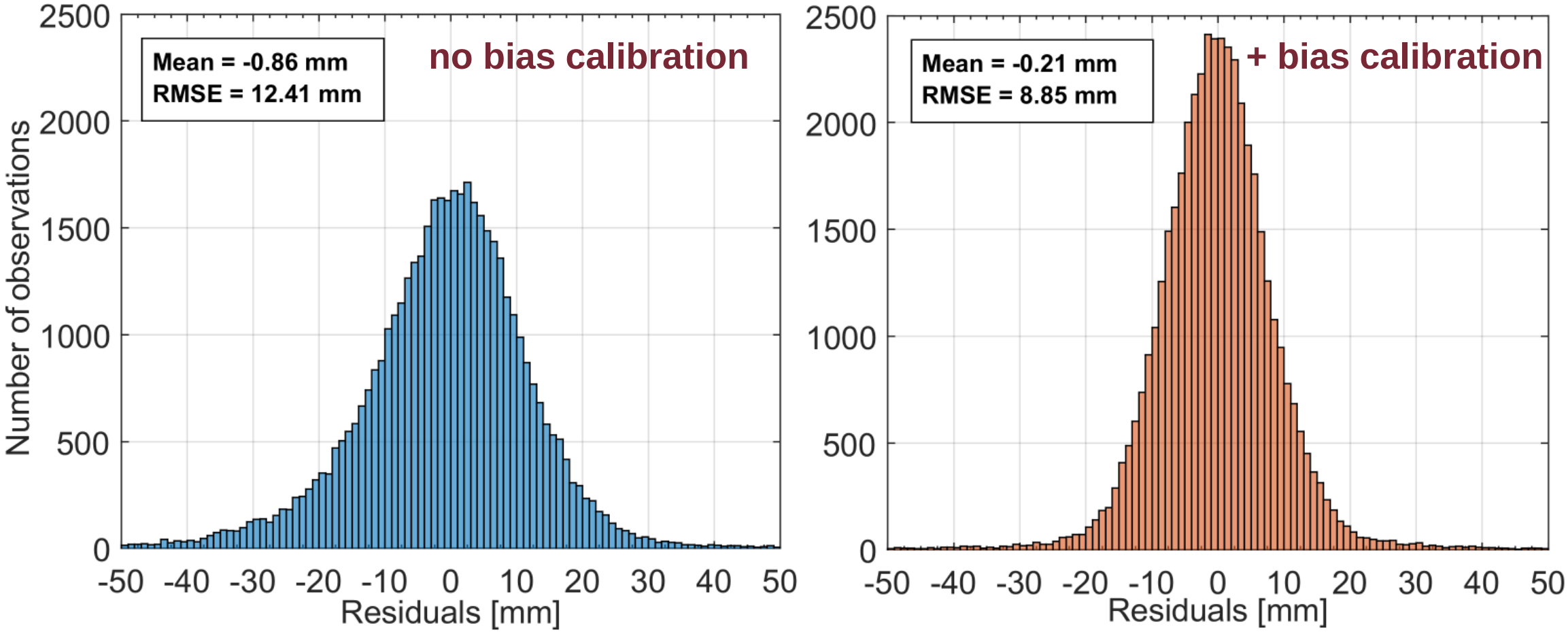
geodetic satellites likewise approach

- Station coordinates
- ERPs
- Geocenter
- Station SLR biases

Combined Sentinel-3A/B + LAGEOS-1/2 Solution

Bernese GNSS Software modified 5.3 Version

Importance of proper SLR station bias calibration for Sentinel-3A/B



SLR residuals to Sentinel-3A GPS based orbits without and with bias calibration

Solution tests– SLR to Sentinel-3A/B

Sentinel-3A/3B (fixed GPS-based orbits)

Solution tests: different network and parameters constraining and a different number of accumulated 1-day orbit combination

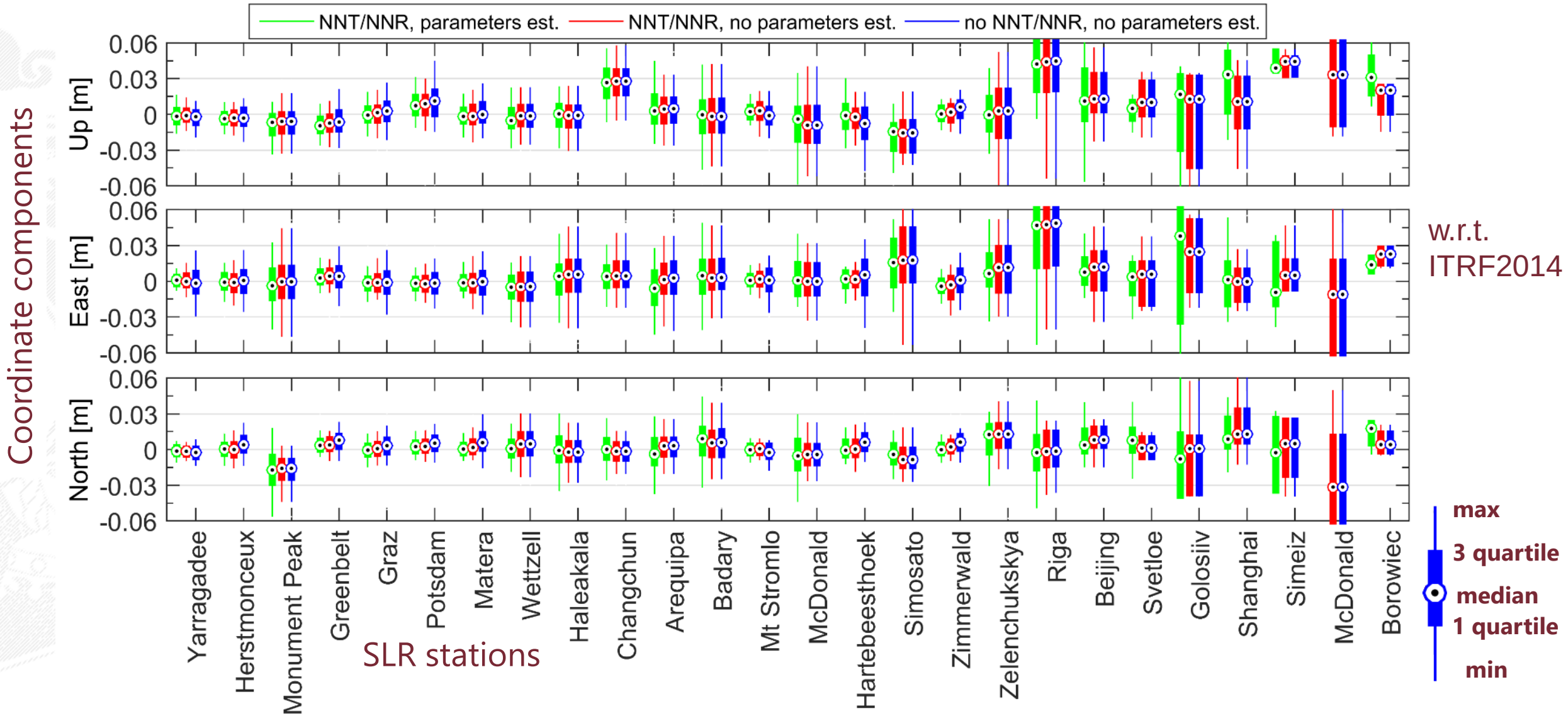
Test1: network constraining: no-net-translation (NNT) no-net-rotation (NNR) with estimation of parameters → SLR station coordinates, geocenter, ERPs

Test2: network constraining: no-net-translation (NNT) no-net-rotation (NNR) without estimation of parameters → SLR station coordinates

Test3: no network constraining and without estimation of parameters → SLR station coordinates

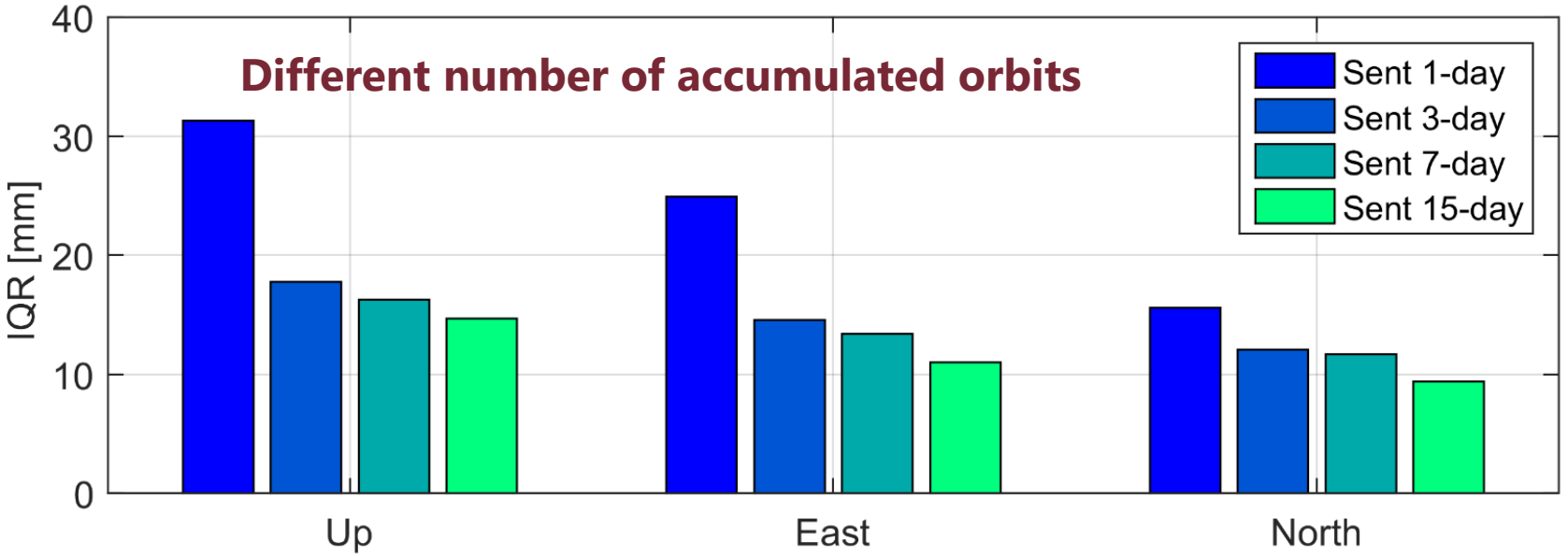
Data span: 2016.4-2018.5

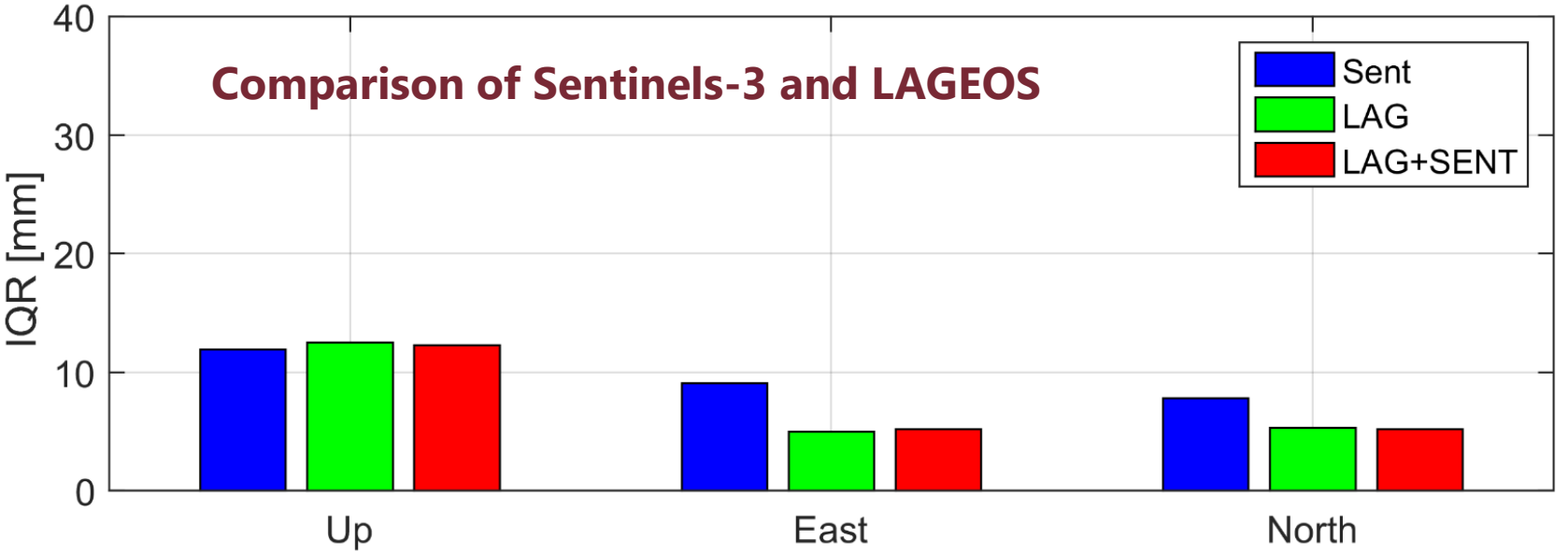
Constraining tests– Sentinel-3A/B



The positioning of SLR stations with the accuracy at the level of 10 mm is possible!
Even without network constraining (blue) provides proper station coordinates (8-12mm-top sites)

A different number of accumulated 1-day orbits





Station coordinates (w.r.t ITRF2014)

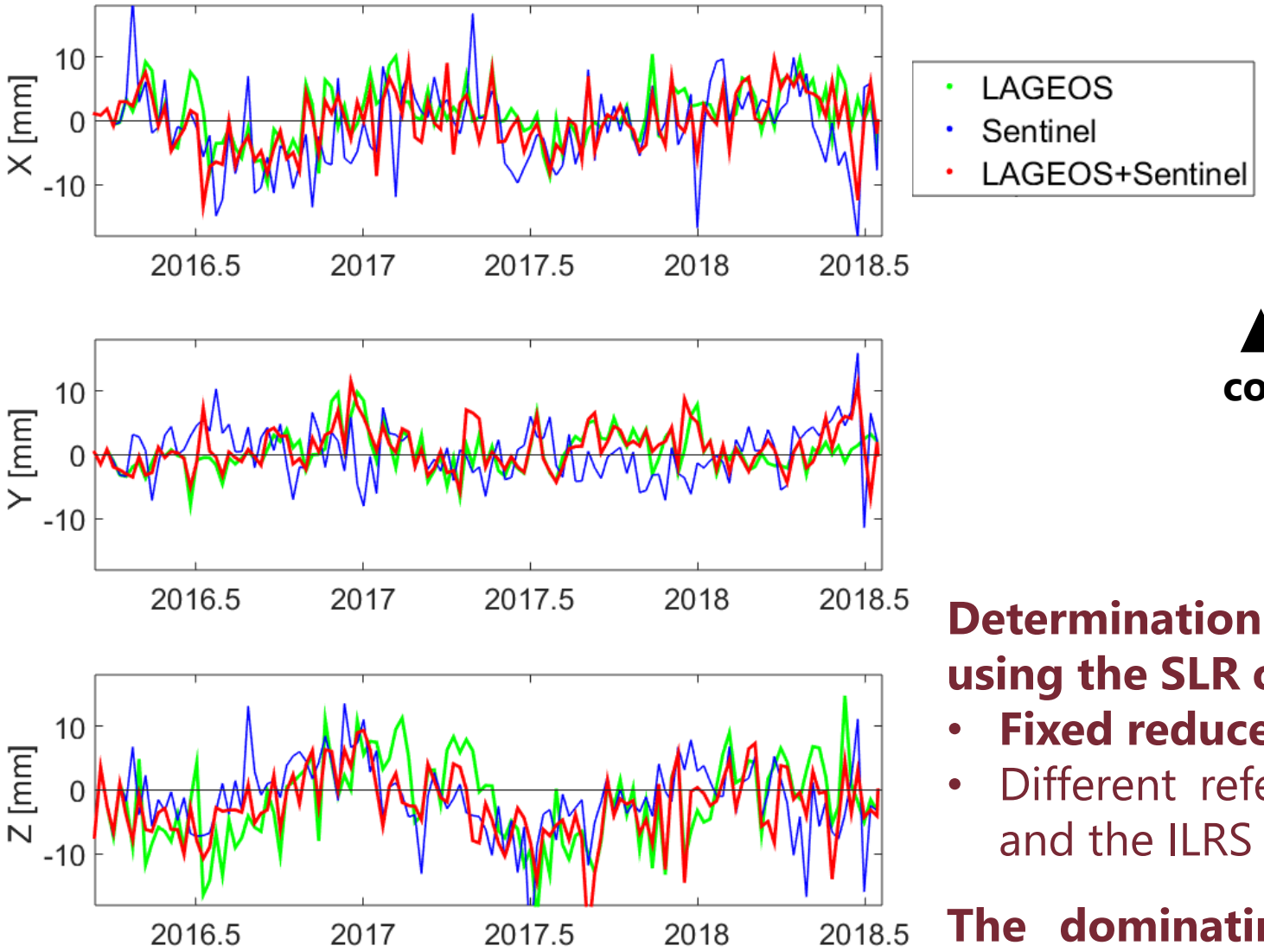
Statistics for all SLR sites

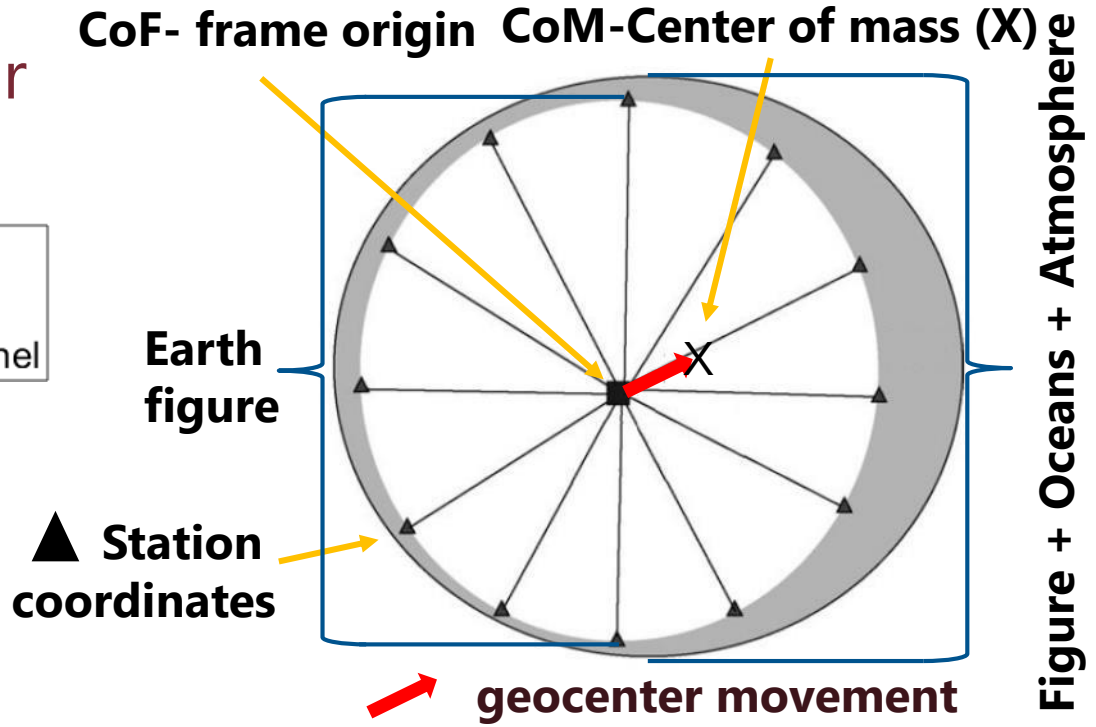
- 1-day Sentinel-3 solutions are insufficient for high-quality coordinates
- Good global coverage can be achieved in **7-day solutions**

Top SLR sites statistics (7-day solutions)

- Sentinel-3 are slightly better for the Up component
- LAGEOS is better for the horizontal components
- **Best results** for all components in the **combined solution**

Combined Sentinels-3A/B+LAGEOS geocenter



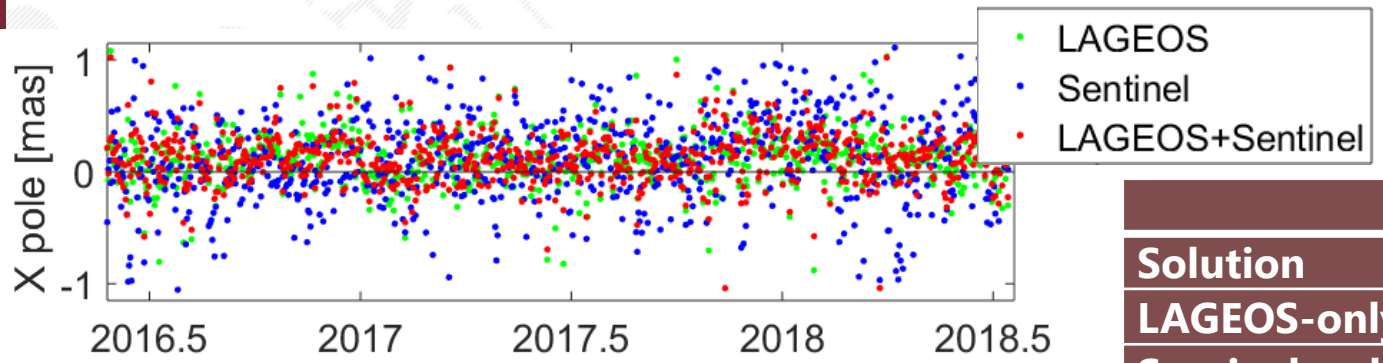


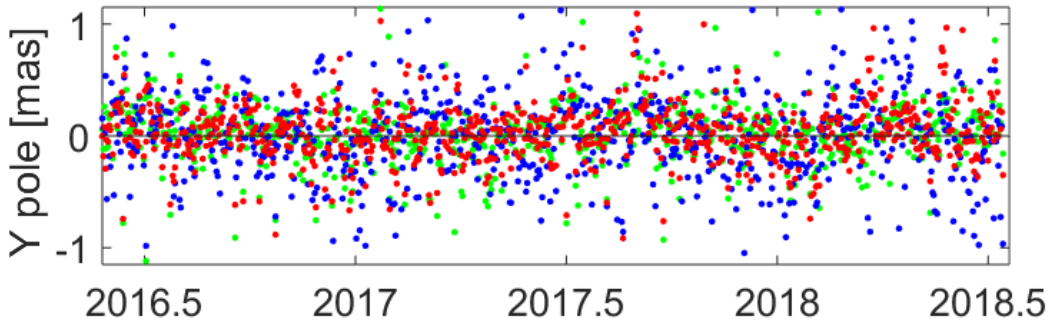
Determination of the geocenter motion is possible using the SLR observations to Sentinels-3, despite:

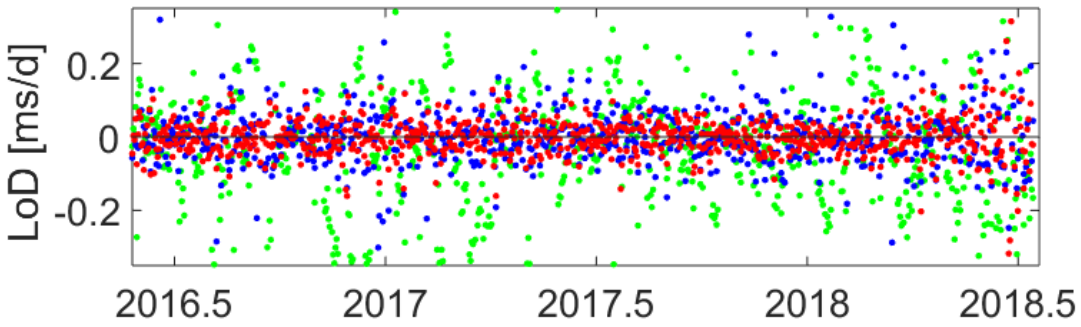
- **Fixed reduced-dynamic** GNSS-based orbits of Sentinels
- Different reference frames for Sentinel-3 orbits (IGS14) and the ILRS network (SLRF2014)

The dominating annual signal in geocenter motion (X and Z components) is well recovered by Sentinels-3

Combined Earth Rotation Parameters w.r.t. IERS-14-C04 series







with a 1-day resolution of parameters

	X pole [µas]		Y pole [µas]		LOD [µs]	
Solution	**mean**	**RMS**	**mean**	**RMS**	**mean**	**RMS**
LAGEOS-only	128	134	47	166	**-98**	**107**
Senrinel-only	109	320	40	314	**-2**	**63**
LAGEOS+Sentinel	134	138	44	189	**-11**	**67**

The **quality of pole coordinates** derived from SLR observations to Sentinel-3A/B is at the level of **300 µas** (1 cm on the Earth surface) when compared to IERS-C04 series. The Sentinel orbits are, however, linked to IGS14 via GPS observations.

The RMS of **Length of Day** (LoD in fact UTC-UT1 with the middle value in **7-day solutions** fixed to IERS-C04) is **reduced by a factor of 2** when compared to LAGEOS-only solutions.

Summary

SLR stations have been providing **observations to a large number** of new active **LEO and GNSS**

SLR observations to active LEO satellite require a **proper station bias calibration**

SLR data and high-quality GPS-based orbits of Sentinel-3A/B allow for the determination of **station coordinates with the accuracy of 10 mm** (best sites), even without network constraining

Reference frame realization based on SLR measurements to Sentinels-3A/B is possible

Best results are obtained from the combined Sentinel-3A/B+LAGEOS-1/2 solutions

SLR observations to Sentinel-3A/B satellites allow for the determination of global geodetic parameters: **geocenter coordinates of 6 mm** (RMS w.r.t LAGEOS), **pole X,Y coordinates of 300 µas** and **LOD of 60 µs/day** (RMS w.r.t IERS-C04-14)

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